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ISC 2022 Lustre BoF

LUSTRE® in HPC, AI and Big Data : Widening Scope, New Features and Roadmap

Tuesday, May 31st / 10:30 – 11:30 AM / Hall E at CCH Hamburg

Frank Baetke (EOFS & for HPE)
Hugo Falter (EOFS & ParTec)
Kevin Harms (OpenSFS & ANL)
Carsten Beyer / Thomas Ludwig (DKRZ)
Peter Jones (EOFS & Whamcloud-DDN)
Andreas Dilger (Whamcloud-DDN)
Jacques-Charles Lafoucriere (EOFS & CEA)

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LUSTRE BoF @ ISC 2022 - Agenda

10:30 – 10:35	Welcome and Introduction	Frank Baetke (EOFS - for HPE) Hugo Falter (ParTec) Kevin Harms (ANL)
10:35 – 10:40	Next Generation Lustre System at DKRZ	Carsten Beyer (DKRZ)
	Short Q&A	
10:40 – 10:50	Lustre News & Community Update	Peter Jones (DDN/Whamcloud)
	Short Q&A	
10:50 – 11:00	Lustre Features and Community Requests	Andreas Dilger (DDN/Whamcloud)
11:00 – 11:20	General Discussion	
11:20 – 11:25	How to Get Involved With Lustre	Jacques-Charles Lafoucriere (CEA)
	Final Q&A	
11:30	Adjourn	

European Open File Systems - Societas Europaea
Co-owner of LUSTRE trademark, logo and assets

EOFS President / Chairman of the Board
- Frank Baetke (acting for HPE)

EOFS Vice-President:
- Jacques-Charles Lafoucriere (CEA)

EOFS Directors:
- Hugo R. Falter (ParTec AG)
- Peter Jones (DDN/Whamcloud)

Members of the Administrative Council:
- Eric Monchalin (Atos)
- Jacques-Charles Lafoucriere (CEA)
- Thomas Stibor (GSI)
- Frank Baetke (acting for HPE)
- Johann Lombardi (Intel)
- Arndt Bode (LRZ)

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OpenSFS

http://opensfs.org

What is OpenSFS?

- OpenSFS facilitates a community around Lustre
  - Organization for both Vendors (Participants) and Users (Members) to discuss features and directions
- Promote Lustre and the Lustre community
- Ensure Lustre remains vendor-neutral and open
- Organize the LUG conference

- **Co-owner of the LUSTRE trademark, logo and assets**

Deutsches Klimarechenzentrum (German Climate Computing Centre)

DKRZ

Next Generation Lustre System

Carsten Beyer
(beyer@dkrz)

German Climate Computing Centre

Lustre at DKRZ

Old system Mistral

ClusterStor CS9000 with 21 PiB (Infiniband)

ClusterStor L300 with 33 PiB (Infiniband)

Will be switched off in June.

Plan: reconfigure L300 as Cloud storage without Lustre

German Climate Computing Centre

HPC system Levante

3 Filesystems based on NVMe / HDD and Infiniband

- HOME
  - 116 TiB NVMe (4 MDS/MDT / 4 OST) – DDN ES400NVX
  - Home directories for users
  - Software tree
  - User quota
  - Directory stripping over all MDT (User toplevel dir)

German Climate Computing Centre

- **PROJECT / WORK**
  - 118 PiB HDD (8 MDS/MDT + 80 OSS/160 OST) – DDN ES7990X
    - WORK directories for customer projects
    - SCRATCH directories for user
    - Pool for common data
  - Usage of Progressive File Layout (PFL)
  - Directory stripping over all 8 MDT (toplevel dir)
  - Project Quota for each WORK/SCRATCH directory
  - Planned: Stratagem/LIPE policy engine for reporting

German Climate Computing Centre

- **FASTDATA**
  - 3.2 PiB NVMe / HDD (4x ES400NVX / 1x ES7990)
    - Approx. 200 TiB NVMe / 3 PiB HDD
    - 16 MDT / 4 OST HDD / 16 OST NVMe
    - 2 Pools (one each for NVMe / HDD)
  - Currently a collaboration project with DDN
    - Hybrid usage NVMe/HDD
    - Hot data/pools
    - Stripping to pools (e.g. with PFL)
  - Maybe later integration in PROJECT/WORK

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Challenge

How to copy approx. 45 PiB of data from old to new system

- Not enough or no LNET Router available
- Configure second set of IP addresses on the DDN Storage as additional @tcp device
- Mounting the new Lustre via @tcp on old system
- Usage of SLURM jobs with pftool/rsync for each project
- Duration approx. 2 months

German Climate Computing Centre

Thank you

Questions ?

Carsten Beyer

beyer@dkrz.de

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Short Q&A

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Lustre News & Community Update

Peter Jones
Whamcloud/DDN

Lustre LTS Releases

Lustre 2.12.8 went GA in December

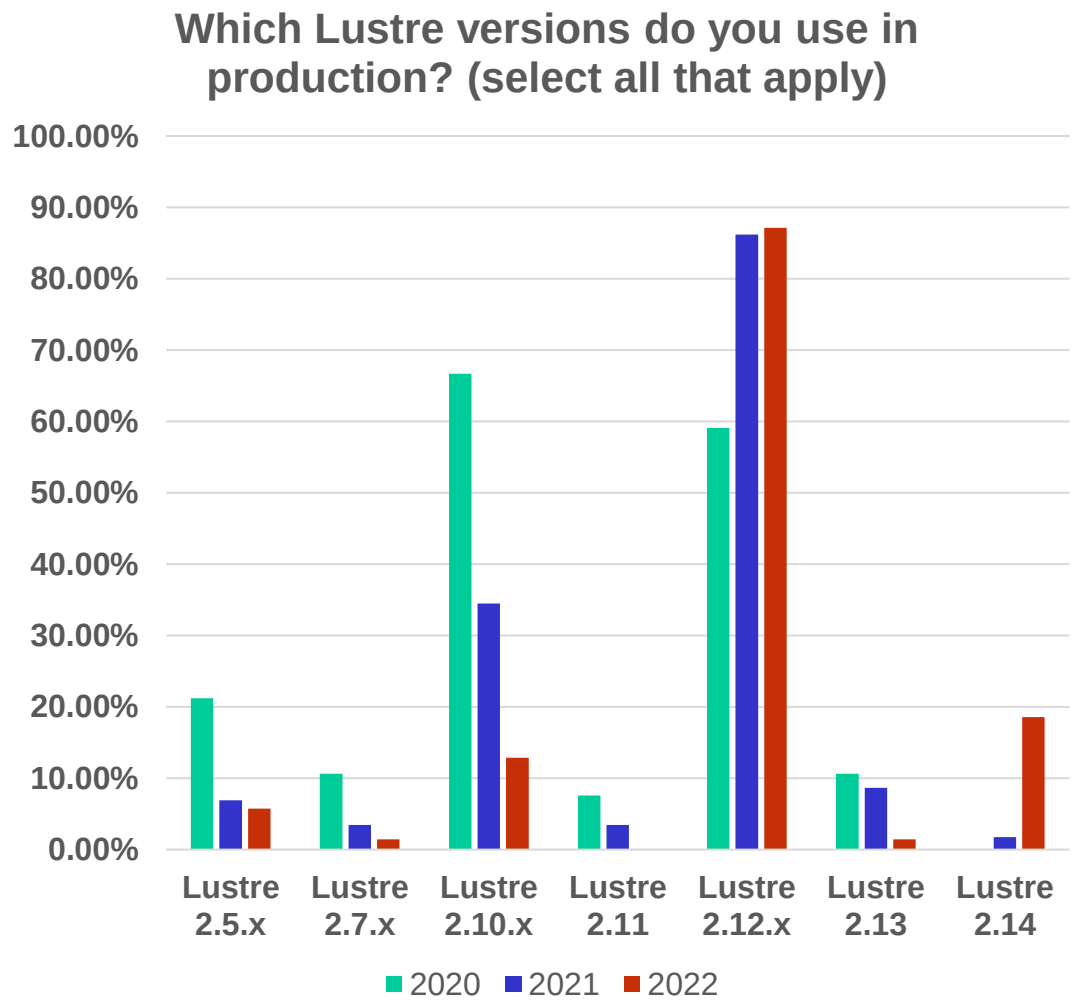
- http://wiki.lustre.org/Lustre_2.12.8_Changelog

Lustre 2.12.9 coming soon

- RHEL 8.6 client support
- https://wiki.lustre.org/Lustre_2.12.9_Changelog

Upcoming Lustre 2.15 release will be next LTS

- Will be transition period between 2.12.x and 2.15.x
- Likely Lustre 2.12.10 will be last 2.12.x release



https://wiki.opensfs.org/Lustre_Community_Survey

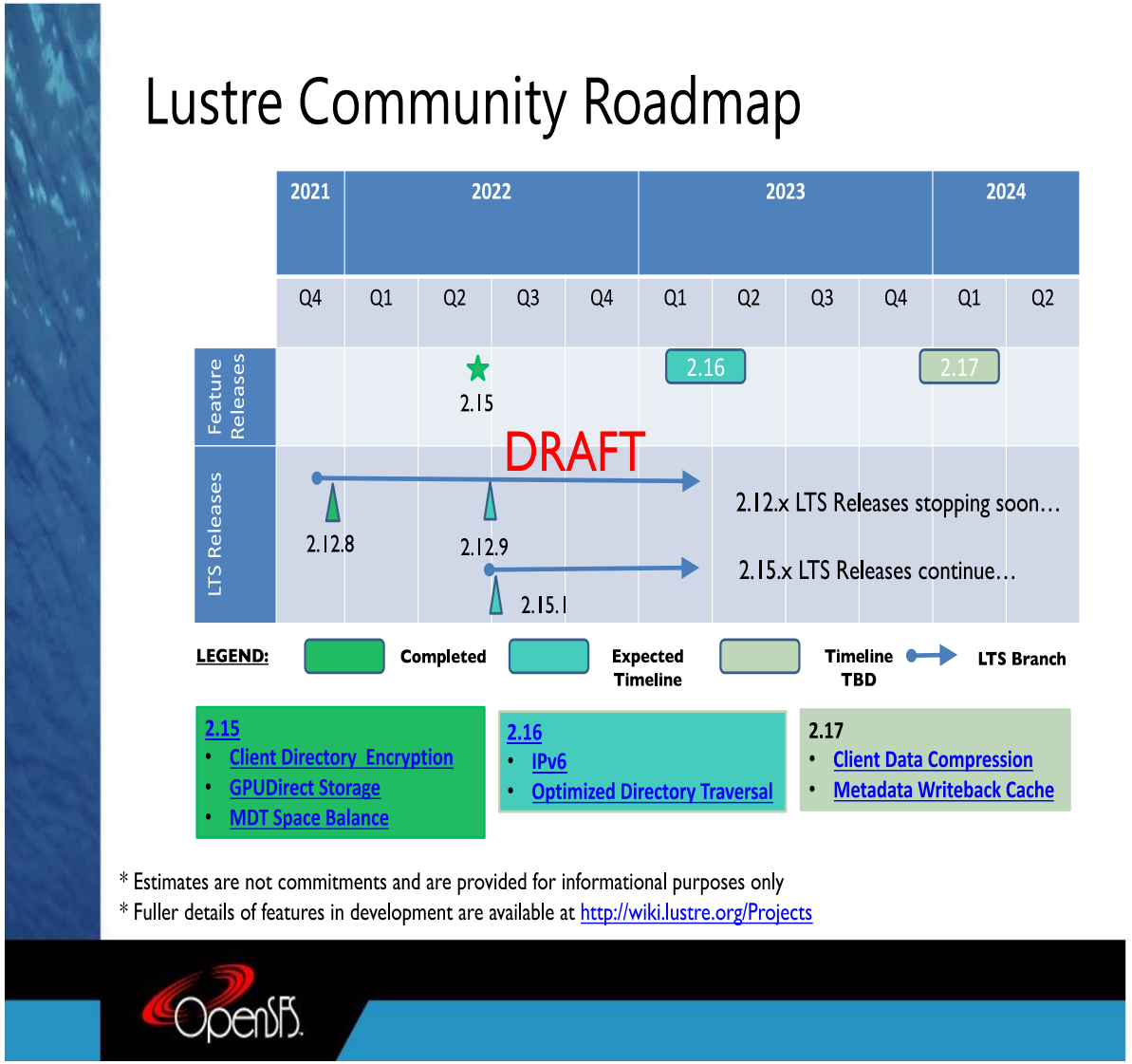
Lustre Major Releases

Lustre 2.15.0 coming soon

- **RC4 likely to be GA version**
- http://wiki.lustre.org/Release_2.15.0
- https://wiki.lustre.org/Lustre_2.15.0_Changelog
- OS support
  - RHEL 8.5 servers/clients
  - RHEL 8.5/SLES15 SP3/Ubuntu 20.04 clients
  - More current distro support will appear in future 2.15.x maintenance releases

Lustre 2.16.0 landings underway

- **Roadmap refresh will finalize after 2.15 GA**



Community Events

Community events were all virtual throughout the pandemic but some in-person events during 2022

Rice Energy 22 Mar 3rd Hybrid event

- https://2022energyhpc.blogs.rice.edu

LUG22 May 9th – 11th Virtual event

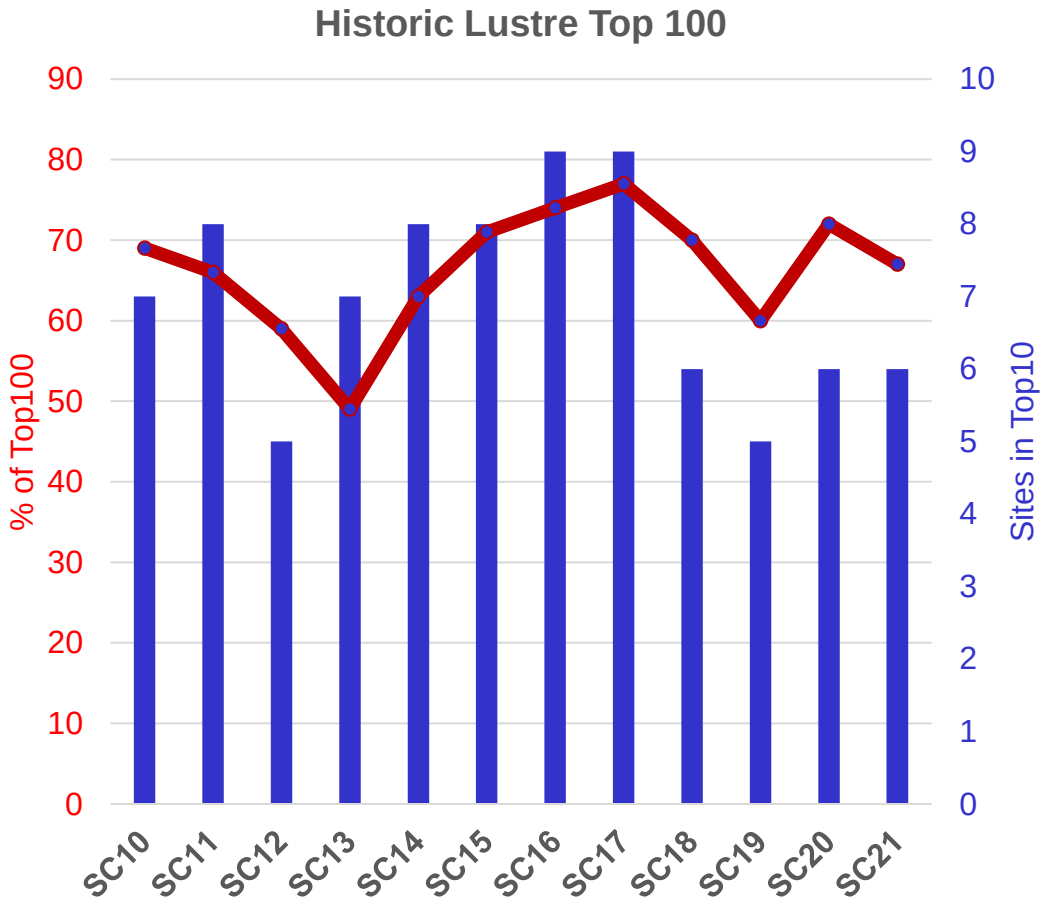
- https://www.opensfs.org/events/lug-2022/

ISC22 Lustre BOF May 31st In-person event (now ☺)

LAD22 Sep 26th – 28th Hybrid event

- https://www.eofs.eu/events/lad22

Dates and format TBA for Australia, China and Japan 2022 LUG events and possible SC22 Lustre BOF



Data analysis of top500.org lists

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Short Q&A

Whamcloud

Lustre 2.16 and Beyond

Andreas Dilger

Lustre Principal Architect

Planned Feature Release Highlights

Whamcloud

- **2.16** opening to land new feature patches
  - **LNet IPv6 addressing** – allow 160-bit NIDs, more flexible server configuration (SuSE)
  - **Optimized Directory Traversal** (WBC1) – cross-directory statahead (WC)
- **2.17** has several major features already lined up
  - **Client-side data compression** – use client CPU to reduce network and storage usage (WC)
  - **Metadata Writeback Cache** (WBC2) – low latency file operations in client RAM (WC)
  - **File Level Redundancy - Erasure Coding (EC)** – efficiently store file redundancy
- **2.18** feature proposals in early discussion stages
  - **Lustre Metadata Redundancy (LMR1)** – MDT0000 service redundancy

LNet Improvements (2.15/2.16)

2.15

- Multiple TCP sockets for 100GigE+ performance (LU-12815, WC)
  - Add `conns_per_peer=N` for `socklnd` (4.1GB/s->9.5GB/s on 100GbE)
  - Auto-configure based on interface speed (e.g. 10Gbps=>2, 100Gbps=>4, …)
- LNet Network Selection Policy (UDSP) (LU-9121, WC)
  - Allow policies for local/remote interface prioritization by NID
    - e.g. primary IB with TCP backup, select "best" router NID for client/server

2.16

- IPv6 NID support (LU-10391, SuSE)
  - Variable-sized NIDs (8-bit type, 8-bit size, 16-bit network, 128-bit+ address)
  - Interoperable with existing current LNDs whenever possible
- Simplified/dynamic server node addressing (LU-14668, WC)
  - Detect added/changed server interfaces automatically (LU-10360)
  - Reduce (and eventually eliminate) static NIDs in Lustre config logs

Client Improvements (ORNL, SuSE, WC)

Whamcloud

- **GPU Direct RDMA** - directly into GPU, bypass CPU (LU-14798, WC, NVIDIA, HPE)
  - A100 2x200Gb IB 36GB/s write, 39GB/s read, 174GB/s with 8x200Gb IB
- **Parallel large DIO** optimization (LU-13798, LU-13799, HPE, WC)
  - Improve single-thread `read()`/`write()` (1.5GB/s->15.8GB/s!)
  - Particular benefits for AIO/DIO and `io_uring` in client kernels 5.1 and later

2.15
- Improved "`lfs find -printf`" option for scanning files (LU-10378, ORNL)

2.16
- `o2iblnd` cleanups for in-kernel OFED (LU-8874, ORNL)
- Buffered/DIO/mmap performance/efficiency improvements (LU-13805, WC)
- Ongoing code style/structure cleanup for upstream submission (ORNL)
- Ongoing updates for newer kernels (ORNL, SuSE)

Backend OSD Improvements (2.16+)

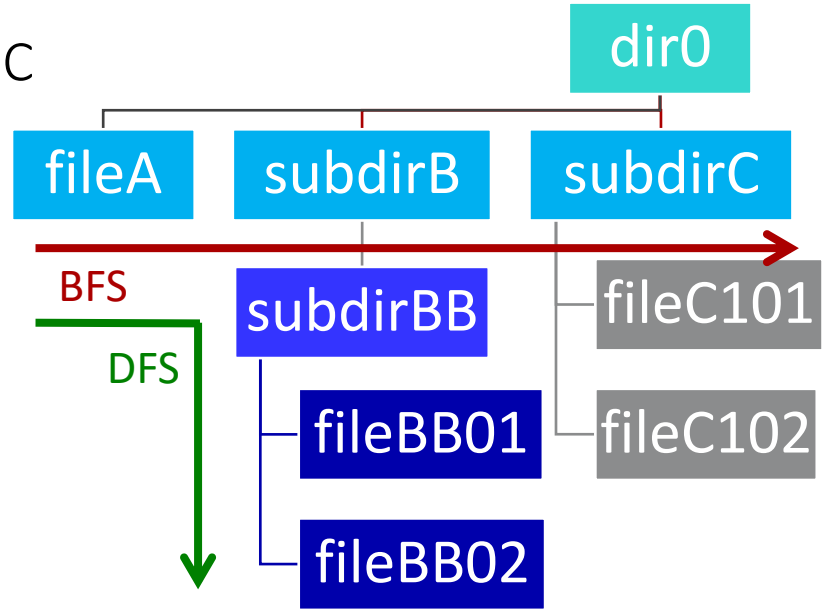
Whamcloud

- Parallel e2fsck for pass2/3 (directory entries, name linkage) (LU-14679, WC)
  - Now slowest part of e2fsck (was 7% of total time, now 70% after pass1/pass5 speedups)
- ZFS 2.1 dRAID VDEVs - declustered parity and hot space (LLNL, HPE, Intel)
- `fallocate()` and `FALLOCATE_FL_PUNCH_HOLE` for ZFS (LU-14157, AEON)
- Improved ldiskfs mballoc efficiency for large/full filesystems (LU-14438, Google, WC)
  - O(1) lookup of power-of-two free space, O(logN) lookup of other sizes
- Improved ldiskfs "`-o discard`" efficiency (LU-14712, Kuaishou, WC)
  - Allow real-time TRIM of flash storage to maintain peak performance
- OST object directory scalability for large OSTs (LU-11912, WC)
  - Large OSTs (500-1000TB) have billions of objects, only 32 dirs per MDT!
  - Wider dir fanout not better, object create/remove access all dirs randomly
  - New OST FID Sequences more often (e.g. 32M vs. 4B objs), retire old SEQ
  - Groups objects by age to limit directory size and improve efficiency

Batched Cross-Directory Statahead (WC 2.16)

Whamcloud

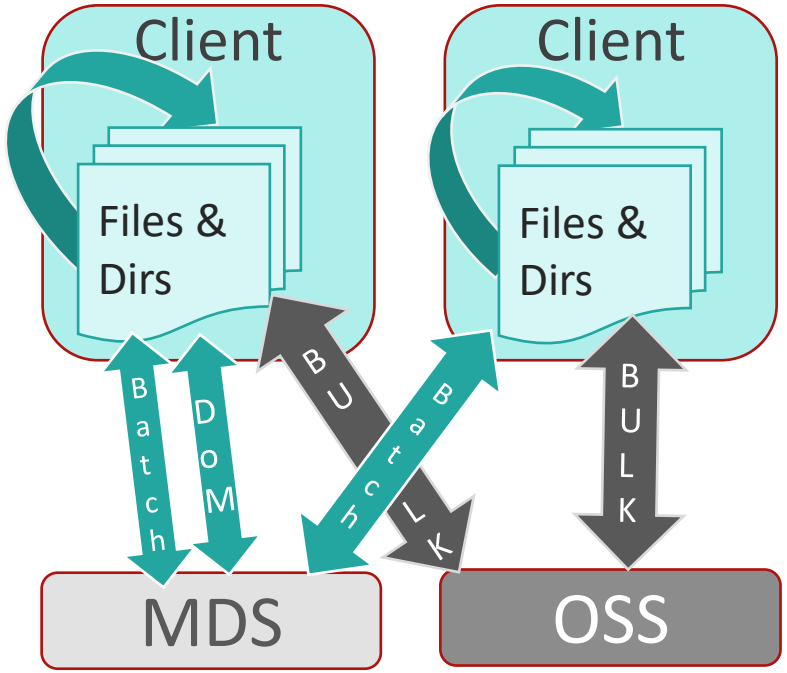
- **Batched RPCs** for multi-update operations (LU-13045)
  - Allow multiple getattrs/updates packed into a single MDS RPC
  - More efficient network and server-side request handling
- **Batched statahead** for `ls -l`, `find`, etc. (LU-14139)
  - Aggregate getattr RPCs for existing statahead mechanism
- **Cross-Directory statahead** pattern matching (LU-14380)
  - Existing statahead only detects `readdir()`-ordered `stat()`
  - Detect pattern for alphanumeric ordered traversal + `stat()`
  - Detect breadth-first (BFS) depth-first (DFS) directory traversal
  - Direct statahead to next file/subdirectory based on pattern



Metadata Writeback Cache (WBC) (LU-10983) (WC 2.16+)

Whamcloud

- Create new dirs/files **in client RAM without RPCs**
  - Lock new directory exclusively at `mkdir` time
  - Cache new files/dirs/data in RAM until cache flush or remote access
- **No RPC round-trips** for file modifications in new directory
- Batch RPC for efficient directory fetch and cache flush
- **Files globally visible on remote client access**
  - Flush top-level entries, exclusively lock new subdirs, unlock parent
  - Repeat as needed for subdirectories being accessed remotely
  - Flush rest of tree in background to MDS/OSS by age or size limits
- Productization of WBC code well underway
  - Some complexity handling partially-cached directories
  - Need to integrate space usage with quota/grant



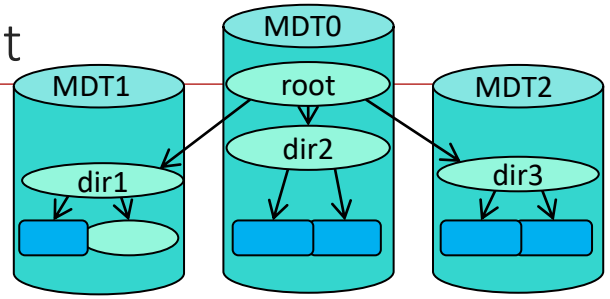
MDT DNE Improvements (WC 2.15+)

Whamcloud

- **DNE MDT Space Balance** - load balancing with normal `mkdir` (LU-13439, LU-13440)
  - Round-robin/balanced subdirs, prefer to stay on parent, limited layout inheritance depth
  - Keep MDTs within free inodes/space (`mdt.*.mdt_qos_threshold_rr=5%`)
- Single-dir migration - `"lfs migrate -m -d <dir>"` (LU-14975)
  - Move only one directory level, instead recusing down full subdirectory tree
- Balanced migration - `"lfs migrate -m -1 <dir>"` (LU-13076)

2.15
  - Auto-select less-full MDTs for each directory, keep inodes local to parent

2.16
- OST object directory scalability for large OSTs (LU-11912)
  - Request new OST FID Sequences more frequently
- DNE locking, migration, remote RPC optimization (LU-15528)
  - Improve distributed transaction performance, reduce lock contention



Lustre Metadata Redundancy (LU-12310) (2.17+)

- **LMR1a: Replicate MDT0000 Services to Other MDS Nodes**
  - Add replication for FLDB, Quota Master, `flock()` across all MDTs
- **LMR1b: DNE Distributed Transaction Performance**
  - DNE2 Distributed Transactions have excessive ordering/sync operations
  - Optimizations improve **all** DNE ops, independent of LMR
- **LMR1c: Replicate Top-level Directories for improved availability**
  - **ROOT/** dir (rarely modified) replicated over MDTs, no file replication
- **Additional LMR2/3 phases to reach full MDT redundancy**
  - Full tree replication, inode replication, configurable per directory
  - Recovery, LFSCK, rebuild replicated directories after MDT loss

Whamcloud

Thank You!
Questions?

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General Discussion

Lustre at CEA

Jacques-Charles Lafoucrière, Thomas Leibovici

ISC 2022

Lustre at CEA: a long history

- In production at CEA since 2005, on the TERA10 supercomputer
  - At that time, Lustre version was … 1.4
  - Initial use in a testbed since 2002 (0.5.16)
- A long history of contributions
  - Nearly 600 patchs written or reviewed by CEA
  - CEA developed key features of Lustre like
    - OST pools
    - HSM
- CEA also develops open-source tools for Lustre
  - *Shine* to ease Lustre FS administration: https://github.com/cea-hpc/shine
  - *Robinhood Policy Engine* to monitor and manage filesystem contents: https://github.com/cea-hpc/robinhood

Lustre file systems at CEA: overview

→ 11 Lustre filesystems and 100PB+ in 4 facilities

TERA/EXA computing center (defense)

- 2 SCRATCH filesystems
  - TERA 1000
  - EXA 1
- STORE filesystem = long-term storage based on HSM
- WORK filesystem = permanent workspace

TGCC computing center (research & industry)

- 2 SCRATCH filesystems
  - Joliot-Curie (Prace Tier 0)
  - Topaze (CCRT)
- STORE filesystem
- 2 WORK filesystems
  - Full HDD
  - Hybrid (SSD+HDD)

TERA+ lab (prototyping)

- 1 filesystem split in 2 workspaces (SCRATCH and WORK)
- 1 filesystem for long term storage (STORE)

Focus on T1K-F, a full-flash Lustre filesystem

T1K-F

- First full-flash filesystem installed at CEA, in 2019
- Configuration:
  - 16 DDN SFA 18KXe
  - 864 NVMe drives (3.2TB, 3DWPD)
  - 128 ports InfiniBand EDR 100Gb
- 2.1 PB @ 1.2 TB/s IOR
- Ranked 6th fastest filesystem at SC19's IO500
  - 3rd of HPC sites

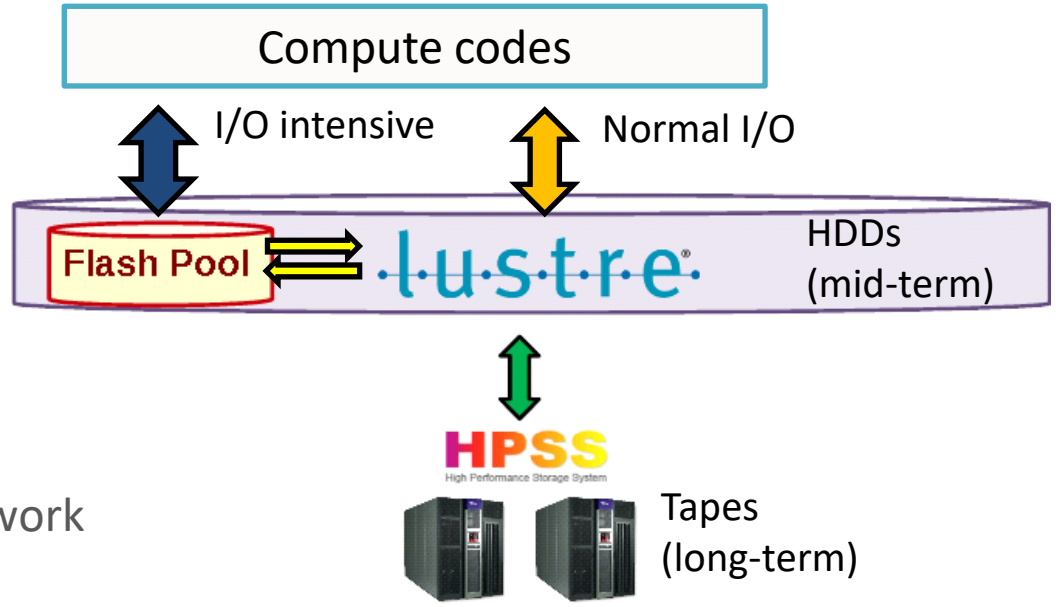
IO500
https://io500.org

# ↑	INFORMATION							IO500	
	BOF	INSTITUTION	SYSTEM	STORAGE VENDOR	FILE SYSTEM TYPE	CLIENT NODES	TOTAL CLIENT PROC.	SCORE ↑	BW (GIB/S)	MD (KIOP/S)
6	SC19	CEA	Tera-1000	DDN	Lustre	128	4,096	210.26	81.01	545.74

Focus on EXA1's STORE: a 3-level hierarchical storage

3 storage technologies in a single Lustre namespace

- NVMe drives (670TB)
- Hard Drive Disks (45PB)
- Tapes (150TB+) -> expandable at will

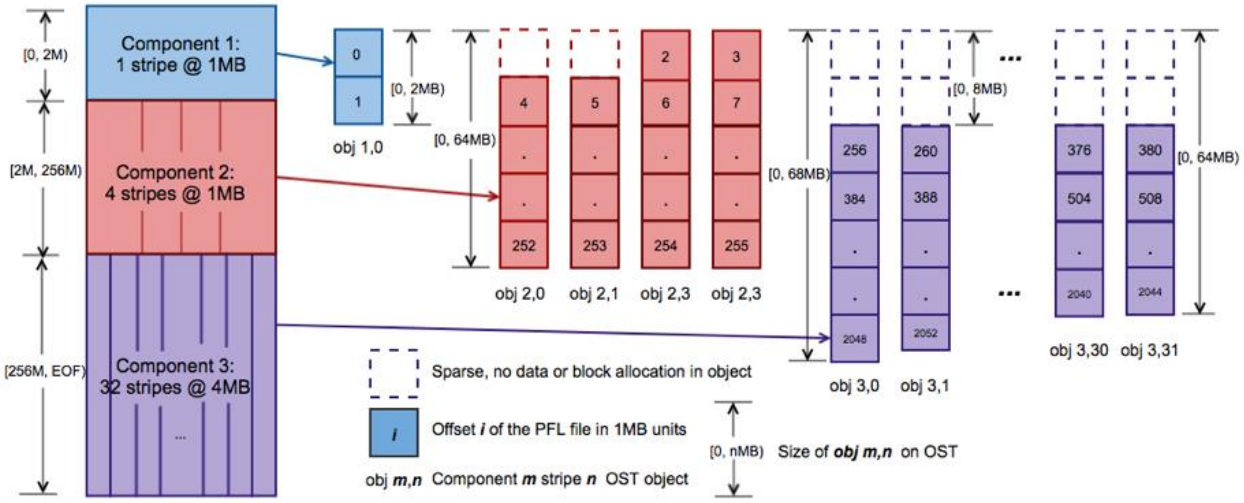


- NVMe and HDD patitioning using the OST pool feature
  - **lfs migrate** operations distributed using the *celery* framework
  - **Robinhood** to schedule data migrations

- HPSS integration using the Lustre/HSM feature
  - Robinhood to schedule data migrations

Lustre features – in used or planed -

- Most used features in production:
  - OST pools + lfs migrate
  - HSM
  - DNE (static)
- Planning to use in the short-term
  - Project quota
  - Data-on-MDS (DoM)
  - Progressive file layout (PFL)
  - LNET Multirail



Mapping from 2055MB PFL file data blocks to OST objects of three components

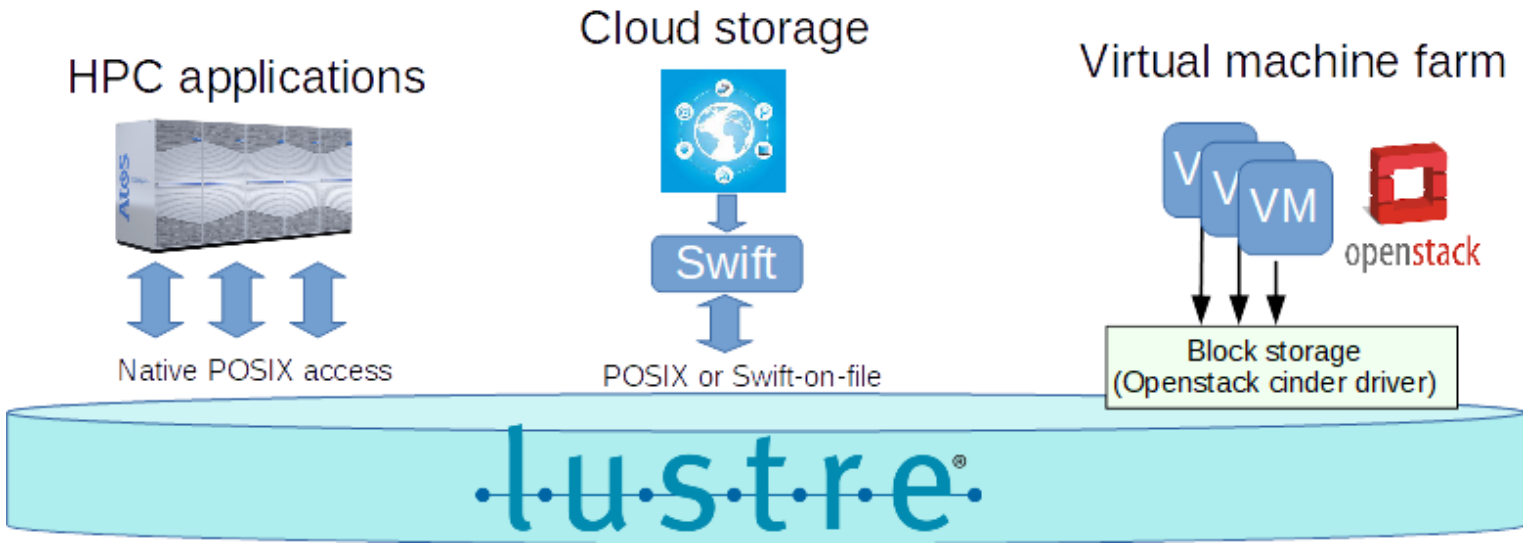
Lustre features – under evaluation -

- Other features of interest (under evaluation):
  - Pool quota
  - Kerberos support
  - Client data encryption / client namespace encryption
  - User Defined Selection Policy (network rules)
  - GPU direct
  - Persistent client cache

Lustre-related developments

Lustre-OpenStack integration (funded by ICEI Eu project)

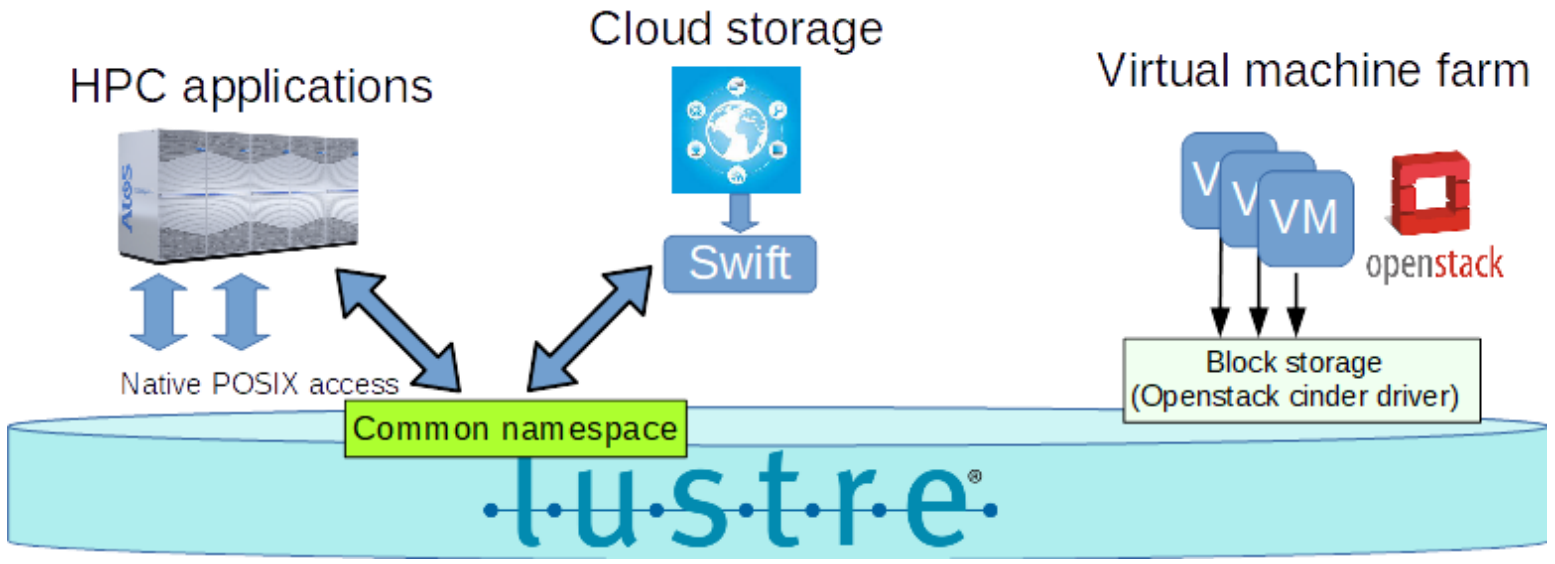
- Benefits: using Lustre as a storage backend for both HPC and cloud usages
- Development includes:
  - Swift-over-Lustre
  - Cinder-over-Lustre



Lustre-related developments

Lustre-OpenStack integration

- Icing on the cake: unified view between Lustre and Swift
  - Bi-directional synchronisation of Lustre and Swift namespaces



Lustre-related developments

Lustre-OpenStack integration

- Developed in the framework of the European project « ICEI », to implement the FENIX infrastructure
  - https://fenix-ri.eu

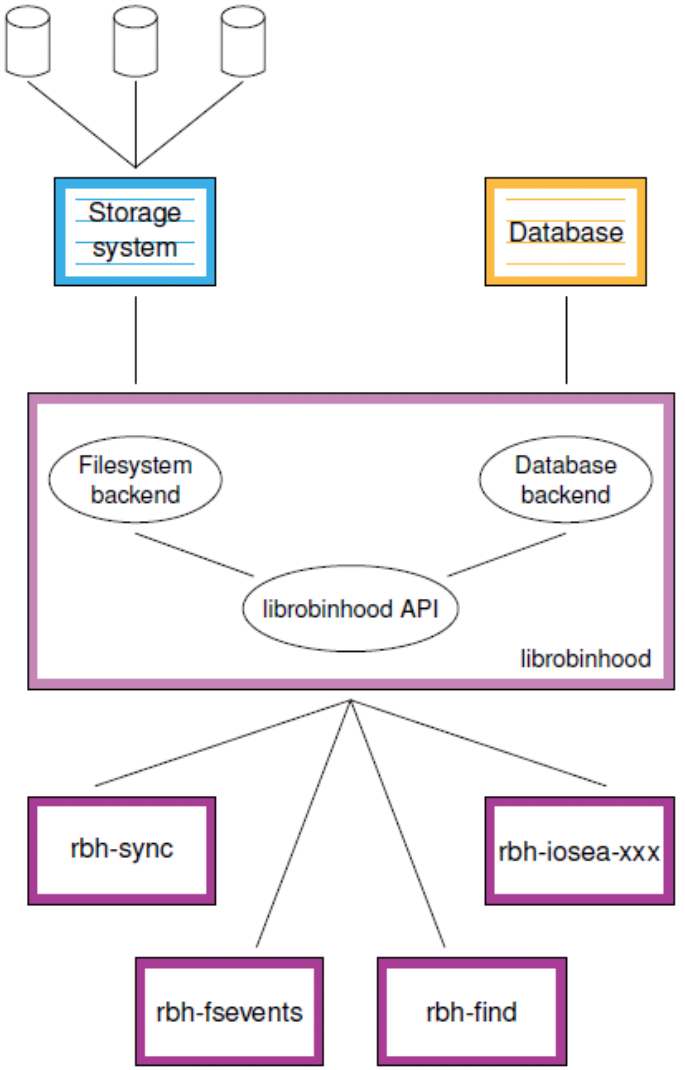
- Sub-contractor: LINAGORA
  - https://linagora.com

- Status:
  - Swift-over-Lustre works. Unified view to be implemented.
  - Cinder-over-Lustre: base feature is done, additional features to be implemented.
  - Target: all code integrated upstream in the coming year.

Lustre-related developments

RobinHood4: next gen policy engine

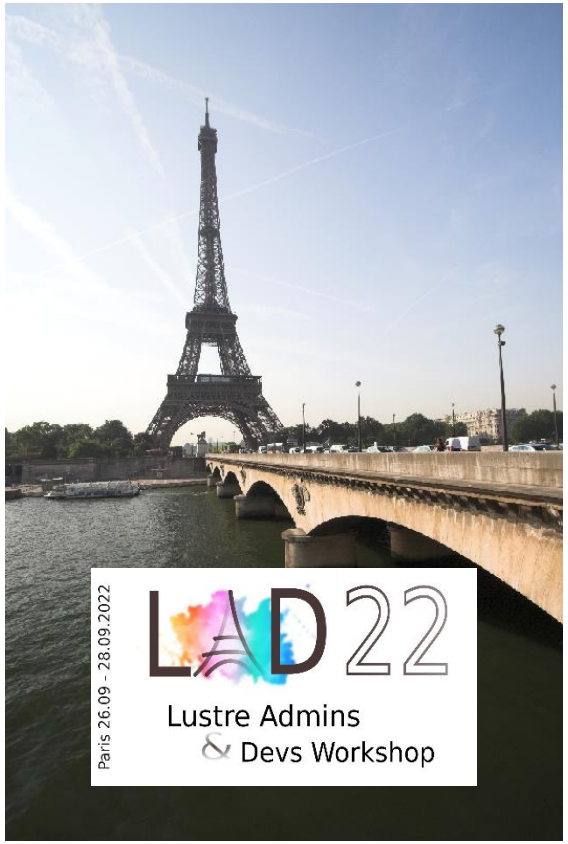
- Mirrors Lustre's filesystem metadata to a **MongoDB** database for higher performance
- CLI commands to:
  - **rbh-sync** to scan FS namespace
  - **rbh-fsevents** to read Lustre changelogs
  - **rbh-find** to query the database using a find-like command
- Flexible use and integration using the **librobinhood API**
- https://github.com/robinhood-suite/



Last but not least…

LAD is back in person!

- Lustre Admin & Dev workshop, with key actors of the Lustre community
- Hybrid event:
  - In person in Hotel des Arts et Métiers, **Paris**, France
  - Live broadcast online
- Save the date: **26 & 27 September 2022** (developer summit on September 28th).
- Keep updated on https://www.eofs.eu/events/lad22



DE LA RECHERCHE À L'INDUSTRIE

Thank you! Questions?

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Final Q&A

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Thank You

Looking forward to meeting you at

LAD'22 (planned as a hybrid event)
in Paris, France - September 26 to 28